Chapter 8. San Diego Regional Survey Sediment Characteristics

INTRODUCTION

The City of San Diego has conducted summer regional surveys of sediment conditions on the mainland shelf off San Diego since 1994 in order to evaluate physical and chemical patterns and trends over a large geographic area. Such region-wide monitoring is designed to assess the quality and characteristics of sediments, as well as provide additional information that may help to differentiate reference areas from sites impacted by wastewater and stormwater discharge. These annual surveys are based on an array of stations randomly selected each year by the United States Environmental Protection Agency (USEPA) using the USEPA probability-based EMAP design. The 1994, 1998, and 2003 surveys were conducted as part of the Southern California Bight 1994 Pilot Project (SCBPP), and the Southern California Bight 1998 and 2003 Regional Monitoring Programs (Bight′98 and Bight′03, respectively). These large-scale surveys included other major southern California dischargers, and included sampling sites representing the entire Southern California Bight (i.e., Cabo Colnett, Mexico to Point Conception). The same randomized sampling design was used for the random sampling surveys limited to the San Diego region (1995–1997, 1999–2002, 2005). In the summer of 2006, the City revisited the 1996 survey sites in order to compare conditions 10 years later.

This chapter presents analyses of sediment particle size and chemistry data collected during the San Diego regional survey of 2006. Descriptions and comparisons of the sediment conditions present in 2006 are included with analyses of levels and patterns of contamination relative to known and presumed sources. Results from the 2006 survey are considered relative to those of the 1996 survey.

MATERIALS AND METHODS

The summer 2006 survey of randomly selected sites off San Diego covered an area from Del Mar south to the United States/Mexico border (**Figure 8.1**). This survey revisited the sites selected for the 1996 regional survey, which was based on the USEPA probability-based EMAP sampling design. Site selection involved a hexagonal grid that was randomly placed over a map of the region. One sample site was then randomly selected from within each grid cell. This randomization helps to ensure an unbiased estimate of ecological condition. The area sampled included the section of the mainland shelf from nearshore to shallow slope

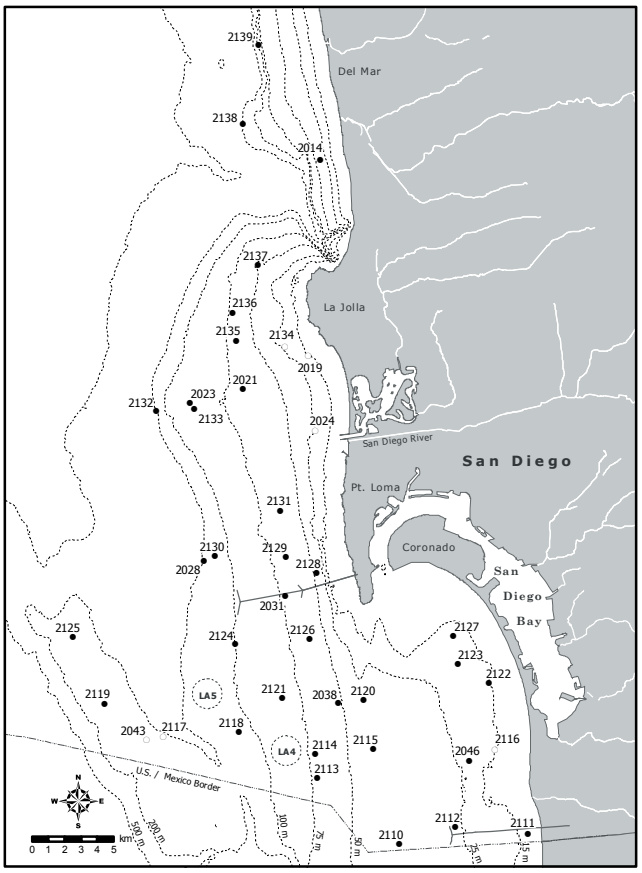

Figure 8.1
Randomly selected regional sediment quality stations sampled off San Diego, CA (August, 2006). Open circles represent abandoned stations (see text).

Table 8.1

A subset of the Wentworth scale representative of the sediments encountered in the SBOO region. Particle size is presented in phi, microns, and millimeters along with the conversion algorithms. The sorting coefficients (standard deviation in phi units) are based on categories described by Folk (1968).

Wentworth scale				Sorting coefficient	
Phi size	Microns	Millimeters	Description	Standard deviation	Sorting
-2	4000	4	Pebble	Under 0.35 phi	very well sorted
-1	2000	2	Granule	0.35–0.50 phi	well sorted
0	1000	1	Very coarse sand	0.50–0.71 phi	moderately well sorted
1	500	0.5	Coarse sand	0.71–1.00 phi	moderately sorted
2	250	0.25	Medium sand	1.00–2.00 phi	poorly sorted
3	125	0.125	Fine sand	2.00–4.00 phi	very poorly sorted
4	62.5	0.0625	Very fine sand	Over 4.00 phi	extremely poorly sorted
5	31	0.0310	Coarse silt		
6	15.6	0.0156	Medium silt		
7	7.8	0.0078	Fine Silt		
8	3.9	0.0039	Very fine silt		
9	2.0	0.0020	Clay		
10	0.98	0.00098	Clay		
11	0.49	0.00049	Clay		

Conversions for diameter in phi to millimeters: $D(mm) = 2^{-phi}$

Conversions for diameter in millimeters to phi: $D(phi) = -3.3219 \log_{10} D(mm)$

depths (12–202 m). Although 40 sites were initially selected for the 1996 and 2006 surveys, sampling at 7 sites in 1996 and 6 sites in 2006 was unsuccessful due to the presence of a rocky reefs. In addition, 7 sites (2014, 2021, 2023, 2028, 2031, 2038, 2046) were sampled in 1995, 1996, 1997, 2005, and 2006.

Each sample was collected from one-half of a chain-rigged 0.1 m^2 double Van Veen grab; the other grab sample was used for macrofaunal community analysis (see Chapter 9). Sub-samples were taken from the top 2 cm of the sediment surface and handled according to EPA guidelines (USEPA 1987). All sediment analyses were performed at the City of San Diego Wastewater Chemistry Laboratory. Particle size analyses were performed using a Horiba LA-920 laser analyzer, which measures particles ranging in size from 0.00049–2.0 mm (i.e., -1 to 11 phi). Coarse sediments (e.g., gravel, pebble, shell hash) were removed from each sample prior to analysis by screening the samples through a 2.0 mm mesh sieve. The retained material was weighed and expressed as the percent coarse of the total sample sieved. Sand was defined as particles ranging from ≥0.0625 to 2.0 mm, silt as particles from <0.0625 to 0.0039 mm, and clay as particles <0.0039 mm (**Table 8.1**). All of these data were standardized to obtain a distribution of coarse, sand, silt, and clay totaling 100%. The clay and silt fractions were then combined to yield the percent fines. Sediment particle size parameters were summarized according to calculations based on a normal probability scale with the sieved coarse fraction included with the >2 mm fraction (see Folk 1968). The calculated parameters include median and mean particle size in millimeters and phi, sorting coefficient (standard deviation), skewness, kurtosis and percent sediment type (i.e., coarse particles, sand, silt, clay).

Chemical parameters analyzed for each sediment sample included total organic carbon (TOC), total nitrogen (TN), total sulfides, trace metals, chlorinated pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyl

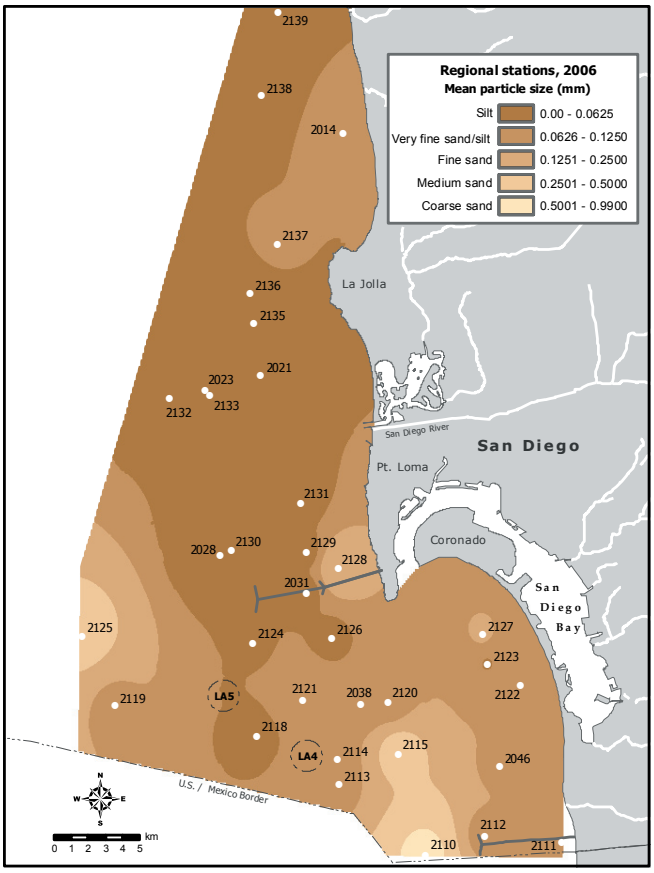

Figure 8.2
Mean particle size distribution for regional sediment quality stations sampled off San Diego, CA (August, 2006).

compounds (PCBs) (see Appendix B.1). These data were generally limited to values above the method detection limit (MDL). However, concentrations below the MDL were reported as estimated values if their presence in the sample could be verified by mass-spectrometry (i.e., spectral peaks confirmed), or as "not detected" (i.e., null) if not confirmed. Zeroes were substituted for all null values when calculating mean values. The data are summarized by depth strata used in the Bight'98 and Bight'03 regional surveys of the entire Southern California Bight (SCB) including shallow shelf (5–30 m), mid-shelf (30–120 m), and deep shelf (120–200 m).

Cumulative distribution functions (CDFs) for TOC, TN, trace metals, and pesticides (i.e., DDT) were established previously for the SCB using data from the SCBPP (see Schiff and Gossett 1998). These reference values are presented as the median (50%) CDF in the tables included herein, allowing for comparison of the San Diego region relative to the entire SCB. Levels of contamination were also evaluated relative to several previously established sediment quality guidelines. These guidelines include the Effects Range-Low (ERL) and Effects Range-Medium (ERM) sensu Long et al. (1995), and the Threshold Effects Level (TEL) and Probable Effects Level (PEL) sensu MacDonald (1994).

RESULTS AND DISCUSSION

Particle Size Analysis

With few exceptions, the overall composition of sediments off San Diego in 2006 consisted of fine sands and silts (**Figure 8.2, Table 8.2**). The general distribution of sediment particles was similar to that of the previous years: higher sand content in shallow nearshore areas, decreasing to a mixture of mostly coarse silt and very fine sand at the mid-shelf region and deeper offshore sites (see City of San Diego 1998, 2000–2003, 2006a, b). Overall, the sediments reflect the diverse and patchy habitats common to the Southern California Bight (SCB). Stations of the mid-shelf strata (30–120 m) represented most of the shelf region off San Diego (n=21). These sites were composed primarily of fine sands with mean particle size of 0.105 mm composed of about 63% sands and 36% fines. By comparison, only 6 sites occurred within the shallow shelf strata at depths ≤30 m, which were slightly more coarse than the mid-shelf strata. Mean particle size at these sites was approximately 0.101 mm, and averaged around 81% sands and 19% fines. Seven deep water sites (120–200 m) contained sediments of 0.090 mm average particle size, including about 57% sand and 41% fines. Coarse sediments (mean >0.5 mm) occurred in shallow waters offshore of the SBOO (station 2110), and included relict sediments typical of the area offshore of the Tijuana River (see **Appendix F.1**). Station 2125 along the Coronado Bank, a southern rocky ridge located offshore of Point Loma at a depth of 150–170 m, was composed of more coarse particles (mean ≥0.3 mm) relative to surrounding sites. Additionally, several areas along the mid-

Table 8.2

Summary of particle size and sediment chemistry parameters for the 2006 regional survey stations. CDF=median cumulative distribution functions (see text); nd=not detected. Bolded values exceed the median CDF. Means=mean of detected values. Area Mean=mean across all stations.

Station	Depth	Mean	Fines	Sand	Sulfides	TN	TOC	HCB	tDDT	tPCB	tPAH	
	(m)	(mm)	(%)	(%)	(ppm)	(%)	(%)	(ppb)	(ppb)	(ppb)	(ppt)	No.
Shallow shelf												
2111	12	0.093	23.4	76.6	33.80	0.027	0.273	nd	nd	440	74.7	6
2122	16	0.096	18.0	81.9	26.20	0.023	0.196	nd	nd	nd	43.4	3
2127	16	0.130	8.4	91.6	22.20	0.023	0.266	nd	nd	nd	70.6	5
2123	19	0.062	40.8	59.2	10.20	0.041	0.395	nd	310	nd	65.2	4
2046	22	0.118	8.4	91.5	0.35	0.018	0.152	nd	nd	nd	30.3	3
2112	26	0.107	12.8	87.2	0.81	0.022	0.200	nd	nd	nd	57.2	5
Mean	19	0.101	18.6	81.3	15.59	0.026	0.247	—	310	440	56.9	4
Mid-shelf												
2128	37	0.203	12.1	87.9	19.50	0.026	0.580	nd	nd	nd	162.1	8
2014	38	0.083	26.4	73.6	2.58	0.047	0.460	nd	560	nd	169.8	9
2120	39	0.081	26.2	73.8	1.54	0.045	0.715	550	nd	nd	64.9	5
2110	40	0.546	0.0	92.7	0.00	0.000	0.054	nd	nd	nd	49.6	4
2115	42	0.301	4.9	94.9	0.00	0.014	0.120	140	nd	nd	40.0	4
2137	48	0.068	35.0	65.0	0.24	**0.057**	**3.150**	nd	nd	nd	144.8	8
2038	52	0.064	33.5	66.4	0.86	**0.055**	0.630	nd	720	nd	39.1	3
2126	62	0.053	42.9	57.1	10.60	**0.073**	**0.853**	nd	690	1990	183.2	11
2131	63	0.046	50.3	49.7	0.57	**0.075**	**0.838**	nd	nd	nd	273.1	13
2135	66	0.043	54.3	45.7	1.08	**0.087**	**1.040**	nd	550	**8440**	170.3	10
2021	67	0.049	46.2	53.8	0.81	**0.068**	**0.838**	nd	nd	nd	208.2	12
2129	67	0.047	48.5	51.5	1.42	**0.070**	**0.755**	nd	580	nd	198.1	12
2114	68	0.089	25.0	75.0	2.12	0.048	0.636	nd	490	nd	91.6	7
2113	69	0.109	18.9	81.1	1.26	0.033	0.361	nd	nd	nd	98.7	8
2136	69	0.047	48.1	51.9	0.62	**0.074**	**0.855**	nd	350	nd	169.3	7
2031	74	0.048	49.0	51.0	2.75	**0.082**	**0.909**	nd	760	nd	233.9	11
2139	77	0.054	41.4	58.6	0.93	0.044	0.531	390	440	nd	110.2	7
2121	83	0.114	64.2	27.6	6.92	**0.070**	**0.973**	nd	750	1300	221.8	12
2133	89	0.048	48.1	51.9	0.53	**0.074**	**1.690**	nd	550	nd	227.0	13
2023	90	0.053	44.4	54.1	0.17	**0.068**	**1.600**	nd	nd	nd	153.4	10
2124	100	0.058	37.0	63.0	0.83	**0.052**	**1.060**	540	nd	nd	115.7	7
Mean	64	0.105	36.0	63.2	2.63	0.055	0.888	405	585	3910	148.8	9
Deep shelf												
2118	123	0.048	44.0	56.0	2.47	**0.071**	**0.967**	220	nd	1240	344.3	15
2119	145	0.116	20.6	79.4	1.19	**0.072**	**4.840**	nd	nd	nd	162.8	12
2130	147	0.042	51.1	48.9	1.12	**0.088**	**1.080**	nd	nd	nd	217.2	12
2125	157	0.300	14.6	72.5	0.27	**0.053**	**4.320**	nd	nd	nd	119.4	9
2138	190	0.038	56.2	43.8	1.91	**0.125**	**1.720**	nd	550	nd	219.3	9
2028	190	0.036	63.2	36.8	3.55	**0.090**	**1.180**	nd	690	nd	195.4	9
2132	197	0.053	40.1	59.9	1.06	**0.086**	**2.230**	nd	490	nd	131.7	8
Mean	164	0.090	41.4	56.8	1.65	0.084	2.334	220	577	1240	198.6	11
Area Mean	76	0.101	34.1	65.0	4.72	0.056	1.073	368	565	2685	142.8	8
50% CDF					na	0.051	0.748	na	1200	2600	na	na

and deep-shelf strata included gravel or coarse black sands. These include one site east of the LA-5 dredge spoils disposal site (station 2121); one site between LA-5 and the PLOO (2124), several sites north of Point Loma (stations 2023, 2132, 2133, 2135, 2139); and 2 sites along the Coronado Bank (2119, 2125). The patchy nature of sediments in these areas has been well documented during previous surveys (see San Diego 1998, 2000–2003, 2006b).

Sediment composition at the shallow water sites in this survey was generally similar to that observed at the 19 and 28-m stations included in the regular semi-annual grid sampling surrounding the SBOO (see Chapter 4). In contrast, deeper grid stations (38 and 55-m) had sediments composed of more sand and less fine materials than comparable mid-shelf samples. This difference may relate to the greater number of grid stations located off-shore and in the southern portion of the South Bay surrounding the U.S.-Mexico border where relict sands are more common.

Generally, sediment particle size composition along the San Diego shelf in 2006 was little different than at the same sites sampled in 1996 (**Appendix F.2**). Only 5 of the 34 stations sampled in 2006 were different by more than 0.05 mm (mean particle size) from the 1996 samples. The mean particle size increased at 2 sites (2110, 2121), while 3 others (2115, 2119, 2137) decreased. Generally, however, sediment composition at the replicate stations sampled over time was remarkably consistent (**Table 8.3**).

Organic Indicators

Concentrations of TOC and TN tended to increase with depth and with increased amounts of fines (Table 8.2). For example, mean TOC values were 0.25% at the shallow water stations, but increased to 0.89% at the mid-shelf stations, and 2.33% at the deep shelf sites. The highest values were collected at sites along the Coronado Bank and northward. Sediments at stations 2119 and 2125 along the Coronodo Bank had concentrations of

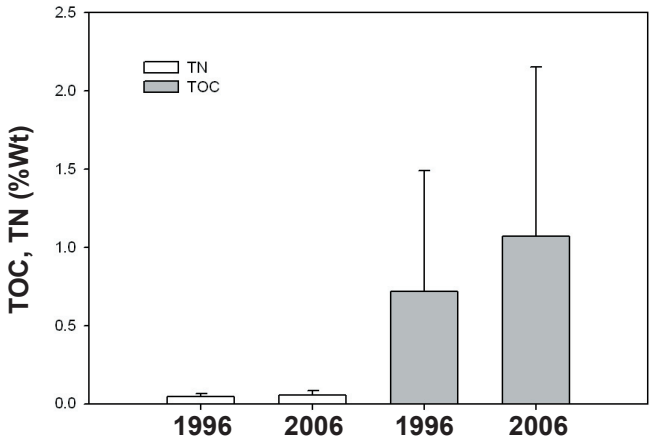

Figure 8.3
Mean concentrations of TOC and TN for the regional sediment quality stations sampled in 1996 vs 2006.

TOC above 4%, while other stations with high TOC concentrations (>1%) occurred from just south of the PLOO (i.e., station 2124) and from Point Loma northward (i.e., stations 2023, 2028, 2130, 2132, 2133, 2135, 2137, 2138). Stations along the Coronado Bank have consistently had high concentrations of organics despite the coarse sediments and low percentages of fines relative to the other deep shelf stations (see City of San Diego 2006b). In contrast, the highest average for sulfides, and the lowest averages for TN and TOC occurred among the shallow-shelf strata stations. Additionally, the shallowest station among the mid-shelf strata (2128) had a high sulfide concentration and relatively lower TN and TOC values.

In general, average concentrations of TOC and TN in sediment samples collected during 2006 appeared slightly higher than in 1996 (**Figure 8.3**). For example, in 2006 approximately 56% of the stations had TOC values that exceeded median CDF levels, compared to 33% in 1996. Similarly, 59% of the TN samples exceeded the median in 2006 relative to 39% in 1996. This change seems to be region-wide and persistent, as most of the 7 repeat stations have increased in TOC and TN concentrations through time (Table 8.3). Episodic events such as storm runoff containing terrestrial detritus and plankton blooms have been considered the primary contributors to increased organic

Table 8.3

Summary of mean particle size (PS=mm) and organic indicators for repeat regional sediment quality stations. TN and TOC=total nitrogen and total organic carbon, expressed as percent weight (wt %); Sulfides=ppm; STD=standard deviation. Bolded values exceed the median CDF (see Table 8.2).

Station	Year	PS	Fines	Sulfides	TN	TOC
2046	1995	0.109	10.8	1.5	0.000	0.092
(22 m)	1996	0.117	8.7	2.3	0.016	0.109
	1997	0.134	6.6	4.5	0.015	0.128
	2005	0.122	9.8	0.2	0.012	0.142
	2006	0.118	8.4	0.3	0.018	0.152
	Mean	0.120	8.9	1.8	0.012	0.125
	STD	0.009	1.6	1.8	0.007	0.024
2014	1995	0.088	23.0	2.1	0.015	0.328
(38 m)	1996	0.095	20.8	26.2	0.037	0.336
	1997	0.082	13.5	80.5	0.040	0.365
	2005	0.079	28.8	2.0	0.046	0.494
	2006	0.083	26.4	2.6	0.047	0.460
	Mean	0.085	22.5	22.7	0.037	0.397
	STD	0.006	5.9	34.0	0.013	0.076
2038	1995	0.051	43.1	3.1	0.042	0.601
(52 m)	1996	0.051	45.0	2.4	**0.064**	0.532
	1997	0.058	39.0	5.8	**0.055**	0.583
	2005	0.055	40.0	0.7	**0.056**	0.617
	2006	0.064	33.5	0.9	**0.055**	0.630
	Mean	0.056	40.1	2.6	0.054	0.593
	STD	0.005	4.4	2.1	0.008	0.038
2021	1995	0.041	52.4	2.6	0.045	0.640
(67 m)	1996	0.044	50.4	1.3	**0.057**	0.642
	1997	0.047	46.8	12.1	**0.076**	0.716
	2005	0.051	44.9	2.8	**0.072**	**1.050**
	2006	0.049	46.2	0.8	**0.068**	**0.838**
	Mean	0.046	48.1	3.9	0.064	0.777
	STD	0.004	3.1	4.6	0.013	0.172
2031	1995	0.102	35.5	3.5	0.048	0.665
(74 m)	1996	0.044	50.4	3.3	**0.065**	**0.749**
	1997	0.047	49.9	2.7	**0.073**	0.697
	2005	0.048	49.0	6.4	**0.079**	**0.850**
	2006	0.048	49.0	2.8	**0.082**	**0.909**
	Mean	0.058	46.8	3.7	0.069	0.774
	STD	0.025	6.3	1.5	0.014	0.103
2023	1995	0.038	54.7	1.3	0.031	0.660
(90 m)	1996	0.063	43.0	1.7	**0.051**	**1.000**
	1997	0.044	51.3	7.7	**0.076**	0.691
	2005	0.210	33.7	1.0	**0.081**	**1.250**
	2006	0.053	44.4	0.2	**0.068**	**1.600**
	Mean	0.082	45.4	2.4	0.061	1.040
	STD	0.072	8.1	3.0	0.020	0.395
2028	1995	0.029	69.8	4.3	**0.055**	**1.070**
(190 m)	1996	0.031	67.1	3.4	**0.086**	**1.200**
	1997	0.033	65.5	7.9	**0.122**	**1.170**
	2005	0.037	61.4	8.1	**0.121**	**1.660**
	2006	0.036	63.2	1.9	**0.125**	**1.720**
	Mean	0.033	65.4	5.1	0.102	1.364
	STD	0.003	3.3	2.8	0.031	0.302

content along the shelf (see City of San Diego 2006a, b). Periodic increases in sulfides seem to be restricted to nearshore waters where anoxic conditions following burial of organic materials from storm runoff such as plant debris and decaying plankton are likely factors (Gray 1981). Finally, comparisons between the semi-annual grid and regional stations were inconsistent in terms of concentrations of the various organic indicators (see Chapter 4). The 2006 regional shallow-shelf samples were higher than the 19- and 28-m grid stations for sulfides and TN (15.6 vs. 4.9 ppm, 0.03 vs. 0.02%, respectively), but lower for TOC (0.25 vs. 0.40%). In contrast, sulfides concentrations were similar between the regional mid-shelf strata and the 38- and 55-m grid stations (2.2 vs 2.6 ppm), but much higher for TOC (0.88 vs. 0.26%) and TN (0.05 vs. 0.02%).

Trace Metals

Fourteen trace metals (i.e., aluminum, antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, tin, and zinc) were detected in sediments from at least 70% of the 34 survey stations in 2006 (**Table 8.4**). Three metals (silver, selenium, thallium) were detected at 20% or fewer stations. Beryllium was not detected at all. Concentrations of several metals (aluminum, copper, iron, manganese, mercury, nickel, zinc) generally correlated with increasing percentage of fines (R^2>0.6, p<0.05) or appeared to be associated with nearby sources of anthropogenic inputs (e.g., ocean outfalls and dredge spoils disposal sites). Average concentrations for 11 metals in deep shelf sediments were higher than in either the shallow or mid-shelf strata. Sediments containing relatively higher concentrations of several metals such as aluminum, iron and manganese occurred primarily at mid-shelf and deep water sites: 2023, 2028, 2031, 2118, 2121, 2126, 2129, 2131, 2132, 2133, 2135, 2136, 2138. Station 2121, located inshore of the LA-5 disposal site, had the highest concentrations of 4 metals (i.e., antimony, lead, tin, and zinc), with the lead concentration of 331 ppm being well above the ERL (46.7 ppm). Overall, this is similar to the general distribution pattern of metals described previously for the SCB (Schiff and Gossett 1998) and other San Diego regional surveys (sees City of San Diego 1998, 2000–2003, 2006b).

Unlike organics, concentrations of trace metals in sediments were relatively similar between 1996 and 2006 (**Table 8.5**). Although there was little difference in sediment concentrations between these 2 years, the sediments at 13 stations sampled in 2006 had 3 or more metals whose concentrations exceeded the median CDF values, whereas only 6 did so in 1996. Aluminum and antimony were the most common trace metals exceeding median CDF values in 2006 with concentrations of each exceeding the median value at 20 stations. However, antimony was not detected in 1996; a result likely related to differences in instrumentation and method detection limits in use at the time. Mean concentrations of most metals were either equivalent or higher in the regional shallow- and mid-shelf strata when compared to the SBOO equivalents. For example, mean concentrations of 10 shallow-shelf and 12 mid-shelf strata metals were higher than the SBOO equivalent by 50% or more.

Other Contaminants: Pesticides, PCBs and PAHs

PAHs occurred at every station in low concentrations during 2006, while pesticides and PCBs were rarely detected (Table 8.2). For example, the pesticides hexachlorobenzene (HCB) and total DDT (the sum of several metabolites) were detected at 5 and 15 sites, respectively. These occurrences were limited to the mid- and deep shelf stations, except for one instance of DDT at shallow-shelf station 2123. Neither substance had concentrations above 800 ppb, and DDT levels were well below the median CDF of 1200 ppb. PCBs were detected at 5 sites. Sediments at station 2135, a northern site located offshore of La Jolla, exceeded the median CDF for PCBs (2600 ppb) with 14 different PCB congeners present and a total concentration of 8440 ppb. Stations 2126, 2121, and 2118 are located towards the south between Point Loma and the LA-5 disposal site and contained from 3–5 PCB congeners each, although total PCB concentrations were below the CDF. PAHs were widely distributed, but at generally low concentrations (<350 ppt). Station 2118, located between the LA-4 and LA-5 dredge spoils disposal areas, had the highest number of PAH compounds (15) and highest total PAH concentration (344 ppt). Overall, pesticide, PCB and PAH contamination was most common and in highest concentrations among sites where the percentage of fines was over 20%. There appears to be some relationship between these contaminants and dredge waste disposal. Large plumes of sediment have been observed spreading across the Point Loma and South Bay regions during the disposal of dredged sediments (see Chapter 2). Consequently, the wide distribution of contaminants via sediment plumes makes it difficult to distinguish other potential sources such as the PLOO, SBOO, or river discharges.

Table 8.4

Concentrations of trace metals (ppm) from regional sediment stations, August 2006. CDF=cumulative distribution function. ERL=effects range low threshold value. nd=not detected. na=not available. See Appendix A.1 for names and periodic table symbols.

Station	Al	Sb	As	Ba	Cd	Cr	Cu	Fe	Pb
Shallow shelf									
2111	11100	0.3	2.29	69.5	0.09	17.8	5.3	14300	24.4
2122	6430	0.2	1.63	27.1	0.09	10.5	2.2	6330	4.5
2127	5050	nd	2.23	17.2	0.05	7.8	1.4	5640	4.5
2123	11200	nd	2.20	48.8	0.13	16.0	5.6	11600	8.4
2046	5380	0.1	0.86	21.9	0.06	9.0	0.8	5750	4.1
2112	5870	nd	1.27	35.5	0.04	9.8	0.0	6140	3.9
Mean	7505	0.2	1.75	36.7	0.07	11.8	2.6	8293	8.3
Mid-shelf									
2128	3190	0.1	1.42	13.7	0.05	12.7	0.6	9940	4.2
2014	11500	nd	3.81	68.1	0.10	18.4	6.1	14600	9.0
2120	7700	nd	2.74	31.2	0.10	13.5	4.2	9880	7.6
2110	1400	0.1	7.10	2.6	0.06	10.7	nd	7020	2.6
2115	1990	nd	2.53	6.3	0.05	7.1	nd	4600	2.5
2137	7110	nd	3.41	35.6	0.12	17.6	3.5	15900	8.3
2038	9950	0.2	2.74	41.1	0.15	15.6	6.1	11100	9.2
2126	13300	0.4	3.30	61.6	0.21	20.8	9.1	15200	12.9
2131	13900	0.4	3.82	62.0	0.18	22.6	9.5	16300	13.6
2135	16000	0.4	3.22	68.2	0.16	25.6	9.8	19000	14.6
2021	11000	nd	3.62	46.2	0.11	19.0	7.1	11700	10.7
2129	15000	0.2	4.48	66.1	0.20	23.5	10.7	16900	14.4
2114	6160	0.1	2.02	19.8	0.10	10.6	3.5	7250	5.6
2113	4490	nd	1.42	13.1	0.05	8.3	1.8	5280	4.3
2136	13200	0.2	3.01	62.5	0.13	22.9	7.7	17100	12.4
2031	1500	0.4	3.81	68.6	0.19	23.5	10.8	17200	12.7
2139	10700	0.2	3.23	79.5	0.07	19.4	5.0	16500	9.1
2121	12500	0.7	3.42	52.4	0.20	20.2	12.4	14800	331.0
2133	12400	0.3	3.77	50.2	0.12	23.8	8.0	18800	11.7
2023	11300	0.3	4.61	74.2	0.09	26.5	6.3	22200	11.1
2124	10400	0.2	2.50	36.6	0.12	17.6	6.9	12800	10.7
Mean	9271	0.3	3.33	45.7	0.12	18.1	6.8	13527	24.7
Deep shelf									
2118	12100	0.3	3.84	44.4	0.12	20.1	14.3	14400	13.3
2119	6130	0.2	4.31	22.3	0.16	24.5	4.5	14600	6.2
2130	12200	0.2	3.61	46.7	0.19	22.2	9.4	15300	11.6
2125	5900	0.4	5.12	51.0	0.15	29.0	3.3	15600	5.3
2138	15800	0.3	3.45	63.9	0.50	26.7	10.3	18300	13.9
2028	17000	0.5	3.32	65.1	0.25	28.6	13.7	18600	15.3
2132	10700	0.4	3.52	34.4	0.45	29.9	7.6	20300	9.7
Mean	11404	0.3	3.88	46.8	0.26	25.9	9.0	16729	10.7
Area Mean	9399	0.3	3.17	44.3	0.14	18.6	6.5	13263	18.9
CDF	9400	0.2	4.80	na	0.29	34.0	12.0	16800	na
ERL	na	na	8.2	na	1.2	81.0	34	na	46.7

Table 8.4 *continued*.

	Station	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
Shallow shelf									
	2111	129	nd	6.8	nd	nd	nd	1.13	25.0
	2122	70	nd	3.4	nd	nd	nd	0.83	12.5
	2127	60	nd	2.3	nd	nd	nd	—	11.1
	2123	112	0.014	6.3	nd	nd	nd	1.24	23.8
	2046	73	nd	2.2	nd	nd	0.24	0.46	5.7
	2112	57	nd	3.3	nd	nd	nd	0.85	11.4
	Mean	83	0.014	4.0	—	—	0.24	0.90	14.9
Mid-shelf									
	2128	69	nd	2.2	0.36	nd	nd	0.51	7.5
	2014	144	nd	6.7	nd	nd	0.35	0.47	22.9
	2120	85	0.013	4.8	nd	nd	nd	1.22	17.9
	2110	20	nd	0.9	nd	nd	nd	0.69	5.7
	2115	19	nd	1.5	nd	nd	nd	1.24	5.8
	2137	90	0.003	5.2	nd	nd	nd	0.78	16.9
	2038	94	0.02	7.0	nd	nd	nd	1.36	20.6
	2126	147	0.031	9.6	0.66	nd	nd	1.20	26.2
	2131	142	0.05	10.0	nd	nd	0.19	1.12	25.2
	2135	164	0.038	10.5	nd	nd	nd	1.06	26.5
	2021	114	0.024	7.9	nd	nd	nd	1.02	18.6
	2129	149	0.048	10.8	nd	nd	nd	1.40	28.9
	2114	60	0.008	5.2	nd	nd	nd	1.15	12.8
	2113	48	nd	3.5	nd	0.02	0.24	1.12	9.0
	2136	139	0.02	8.9	nd	nd	nd	0.95	21.5
	2031	151	0.05	10.8	nd	nd	nd	1.71	33.1
	2139	119	0.008	6.7	nd	nd	nd	0.10	21.0
	2121	116	0.05	9.0	nd	nd	nd	8.99	40.6
	2133	126	0.022	9.9	nd	nd	nd	0.99	21.5
	2023	135	0.018	9.0	nd	nd	nd	0.68	24.0
	2124	95	0.022	7.5	nd	nd	nd	0.77	20.2
	Mean	106	0.027	7.0	0.51	0.024	0.26	1.36	20.3
Deep shelf									
	2118	111	0.074	9.8	0.32	nd	nd	1.22	25.9
	2119	42	0.006	7.3	0.29	nd	nd	0.32	14.3
	2130	115	0.035	11.3	nd	nd	nd	0.79	21.9
	2125	33	0.004	6.3	nd	nd	nd	0.18	14.7
	2138	145	0.031	12.0	0.32	nd	nd	0.91	24.2
	2028	150	0.047	16.0	0.36	nd	nd	0.48	29.5
	2132	92	0.021	10.0	0.29	nd	nd	0.80	22.8
	Mean	98	0.031	10.4	0.31	—	—	0.67	21.9
	Area Mean	100	0.027	7.2	0.37	0.02	0.25	1.14	19.7
	CDF	na	0.040	na	0.29	0.17	na	na	56.0
	ERL	na	0.15	20.9	na	1.0	na	na	150

Table 8.5

Summary of mean trace metals concentrations (ppm) for 7 repeat regional survey stations. See Appendix A.1 for names and periodic table symbols.

Station	Year	Al	Sb	As	Be	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Sn	Zn
2046	1995	6050	0.0	1.65	0.00	9.7	0.0	6460	0.00	—	0.000	0.00	0.00	—	12.90
(22 m)	1996	4480	0.0	1.75	0.00	8.2	2.5	5040	0.00	49	0.000	0.00	0.00	0.00	0.00
	1997	5220	0.0	1.58	0.00	9.6	2.1	4910	0.00	54	0.000	0.00	0.00	0.00	10.80
	2005	10000	0.0	1.48	0.00	14.9	2.4	13300	0.00	350	0.000	3.37	0.00	0.00	25.50
	2006	5380	0.1	0.86	0.00	9.0	0.8	5750	4.13	73	0.000	2.18	0.00	0.46	5.65
	Mean	6226	0.0	1.46	0.00	10.3	1.6	7092	0.83	131	0.000	1.11	0.00	0.11	10.97
	Std	2182	0.1	0.35	0.00	2.7	1.1	3525	1.85	146	0.000	1.58	0.00	0.23	9.53
2014	1995	10600	0.0	3.38	0.22	14.3	7.5	14800	0.00	—	0.000	7.30	0.00	—	32.80
(38 m)	1996	7630	0.0	3.29	0.00	13.5	5.5	9820	0.00	96	0.000	6.20	0.00	0.00	27.10
	1997	10900	0.0	4.48	2.75	16.9	8.0	11500	0.00	118	0.000	9.60	0.00	0.00	33.30
	2005	19200	0.0	3.94	0.36	24.7	8.0	19400	6.93	313	0.000	7.91	0.00	0.00	46.30
	2006	11500	0.0	3.81	0.00	18.4	6.1	14600	9.02	144	0.000	6.72	0.00	0.47	22.90
	Mean	11966	0.0	3.78	0.67	17.6	7.0	14024	3.19	168	0.000	7.55	0.00	0.12	32.48
	Std	4246	0.0	0.43	1.15	4.1	1.1	3645	4.07	86	0.000	1.31	0.00	0.20	8.84
2038	1995	10700	0.0	3.31	0.20	20.1	8.9	13700	6.40	—	0.000	10.30	0.00	—	29.80
(52 m)	1996	9960	0.0	4.19	0.23	16.6	8.3	11700	0.00	92	0.095	8.50	0.00	0.00	29.50
	1997	10900	0.0	2.38	0.25	16.3	8.0	11000	0.00	89	0.000	11.10	0.35	0.00	29.00
	2005	17400	0.0	3.59	0.30	22.3	8.9	18400	7.03	263	0.000	9.41	0.00	0.00	39.30
	2006	9950	0.2	2.74	0.00	15.6	6.1	11100	9.20	94	0.020	6.98	0.00	1.36	20.60
	Mean	11782	0.0	3.24	0.20	18.2	8.0	13180	4.53	134	0.023	9.26	0.07	0.34	29.64
	Std	3170	0.1	0.71	0.12	2.9	1.1	3114	4.26	86	0.041	1.60	0.15	0.68	6.62

SUMMARY AND CONCLUSIONS

Although the presence of canyons, peninsulas, bays, and alluvial fans from rivers contribute to the complexity of sediment composition and origin along the San Diego shelf (see Emery 1960), the distribution of sediment particles off San Diego in 2006 was similar to that of previous years and to the Southern California Bight (SCB) in general. There was a trend towards higher sand content in shallow nearshore areas and increased fine sand and silt at the deeper offshore sites. Exceptions to the general pattern occurred in shallow waters offshore of the SBOO, and along the Coronado Bank, a southern rocky ridge located offshore of Point Loma at a depth of 150–170 m. Additionally, several mid-shelf areas contained coarse sediments (black sands or gravel) relative to most mid-shelf stations. These included an area near the EPA-designated disposal sites (LA-4 and LA-5), an area surrounding the Point Loma Ocean Outfall (PLOO) discharge site, and patches of coarse sediments northward of the San Diego River and towards La Jolla Canyon. The patchy nature of sediments in these areas has been well documented during previous surveys (see City of San Diego 1998, 2000–2003, 2006a, b).

There has been little change in sediment composition or average particle size since 1996 when these sites were first sampled. Only 5 of the 34 sites changed in mean particle size between the 1996 and 2006 surveys. Moreover, the 7 repeat stations sampled in 1995–1997 and 2005–2006 maintained remarkably consistent sediment composition.

Patterns in sediment chemistries followed the expected relationship of increasing concentrations with decreasing particle size (see Emery 1960,

Table 8.5 *continued*

Station	Year	Al	Sb	As	Be	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Sn	Zn
2021	1995	12600	0.0	4.87	0.25	16.8	7.1	15900	0.00	—	0.000	9.70	0.24	—	32.90
(67 m)	1996	10200	0.0	4.73	0.22	19.8	8.9	13600	0.00	106	0.074	9.10	0.26	13.00	30.50
	1997	14300	0.0	4.76	0.28	21.8	10.9	14100	0.00	113	0.000	10.60	0.28	0.00	34.20
	2005	18000	0.0	3.38	0.35	24.5	9.2	19500	8.12	290	0.000	9.32	0.00	0.00	44.90
	2006	11000	0.0	3.62	0.00	19.0	7.1	11700	10.70	114	0.024	7.85	0.00	1.02	18.60
	Mean	13220	0.0	4.27	0.22	20.4	8.6	14960	3.76	156	0.020	9.31	0.16	3.51	32.22
	Std	3082	0.0	0.63	0.13	2.2	1.4	2901	4.81	78	0.030	0.98	0.14	5.50	9.40
2031	1995	15100	0.0	4.03	0.00	24.6	13.3	18800	7.80	—	0.000	11.00	0.00	—	43.10
(74 m)	1996	12900	0.0	5.64	0.00	20.2	9.8	14400	5.70	123	0.096	11.00	0.00	0.00	40.20
	1997	18900	0.0	4.80	1.54	26.3	12.7	16300	0.00	149	0.000	14.20	0.26	0.00	44.00
	2005	24300	0.0	4.23	0.40	30.5	11.9	22700	11.60	336	0.048	12.40	0.00	0.00	54.20
	2006	1500	0.4	3.81	0.00	23.5	10.8	17200	12.70	151	0.050	10.80	0.00	1.71	33.10
	Mean	14540	0.1	4.50	0.39	25.0	11.7	17880	7.56	190	0.039	11.88	0.05	0.43	42.92
	Std	8475	0.2	0.73	0.67	3.8	1.4	3128	5.08	98	0.040	1.45	0.12	0.86	7.62
2023	1995	15800	0.0	6.73	0.47	35.5	11.4	32200	0.00	—	0.000	11.00	0.29	—	45.30
(90 m)	1996	10400	15.2	3.99	0.33	28.6	8.8	23600	0.00	126	0.065	10.60	0.26	15.00	38.70
	1997	14600	0.0	5.53	0.32	30.3	11.0	22500	0.00	130	0.000	10.10	0.34	0.00	45.10
	2005	20900	0.0	7.69	0.69	39.4	10.9	37700	9.66	258	0.000	12.20	0.00	0.00	61.30
	2006	11300	0.3	4.61	0.00	26.5	6.3	22200	11.10	135	0.018	9.00	0.00	0.68	24.00
	Mean	14600	3.1	5.71	0.36	32.1	9.7	27640	4.15	162	0.017	10.58	0.18	3.92	42.88
	Std	4121	6.6	1.41	0.25	4.9	1.9	6507	5.24	55	0.027	1.15	0.15	6.40	13.39
2028	1995	18000	6.0	3.04	0.27	28.3	15.1	19200	7.10	—	0.000	14.00	0.58	—	42.20
(190 m)	1996	16900	0.0	2.98	0.33	28.9	14.1	17200	0.00	138	0.073	15.80	0.54	0.00	40.30
	1997	19300	9.7	2.84	0.29	28.7	15.3	16100	6.20	124	0.000	16.60	0.57	0.00	44.90
	2005	25500	0.0	3.06	0.46	35.5	15.4	23600	9.28	310	0.057	16.90	0.37	0.00	57.80
	2006	17000	0.5	3.32	0.00	28.6	13.7	18600	15.30	150	0.047	16.00	0.36	0.48	29.50
	Mean	19340	3.2	3.05	0.27	30.0	14.7	18940	7.58	181	0.035	15.86	0.49	0.12	42.94
	Std	3577	4.4	0.17	0.17	3.1	0.8	2872	5.52	87	0.034	1.13	0.11	0.24	10.16

Anderson et al. 1993, Schiff and Gossett 1998). Concentrations of organic indicators, metals, and other contaminants were higher along the mid-shelf and deep water strata where the percentage of fines was typically greatest. As in prior years, some of the highest contaminant loads occurred near the LA-4 and LA-5 dredge disposal sites. However, there was a marked decrease in concentrations of various constituents, particularly TOC, TN, and trace metals, relative to 2005 when concentrations were substantially higher as a result of heavy rains and non-point source discharges. In contrast, sulfide concentrations increased significantly in shallow-shelf sites in 2006 relative to 2005. This increase is likely a residual affect of the large organic load and plankton blooms experienced in 2005. Results from the repeat stations showed an incremental, but consistent increase in TOC and TN over the past 10 years, while concentrations of sulfides and trace metals were variable over time.

Although pesticides, PCB, and PAH concentrations were generally low in 2006, the pattern of detection was similar to that seen previously. Values were

highest across the mid-shelf and deep water strata where the percentage of fines was greatest. PCBs were detected at only 5 sites with the highest concentration occurring north of La Jolla. Chlorinated pesticides were detected in sediments at over 50% of the sites, while PAHs were more widespread, but more concentrated near the EPA-designated disposal sites as in past surveys. Finally, the regional survey data did not show any pattern of contamination relative to wastewater discharge from the SBOO.

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